

# DINOFLAGELLATES OF THE GULF OF MEXICO

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Dinoflagellates are important in the natural economy of the Gulf of Mexico as they are in all waters of the world. In marine phytoplankton they are usually outnumbered by diatoms, but they are second in importance to the diatoms as fundamental synthesizers of organic material in the sea. On the other hand, to the dinoflagellates belong most of the organisms which cause "red water," mass mortality of marine organisms, and paralytic shellfish poisoning. A thorough knowledge of the dinoflagellates is necessary to a clear understanding of the basic biology of the Gulf of Mexico.

Despite the importance of these organisms, the Gulf of Mexico is almost a terra incognita in respect to our knowledge of the dinoflagellate plankton. Very few oceanographic expeditions have included the Gulf in their itinerary, and those that visited the Gulf have not reported on any dinoflagellate collections.

Many species of dinoflagellates have a world-wide distribution, especially the offshore forms. Many of these can be expected in the Gulf. It is very likely that the pelagic species of the Gulf will be found to be similar to those of the tropical Atlantic, although the general composition of the flora may be different. The inshore, or neritic, plankton may well contain species peculiar to or at least characteristic of the Gulf of Mexico or of certain areas of the coast line. The dinoflagellate fauna of the open Gulf is very likely quite similar to that of the Caribbean and the tropical Atlantic.

As far as the dinoflagellates are concerned, there are three general habitats in the Gulf of Mexico: the offshore waters, the neritic waters, and the sandy beaches.

The offshore waters of the Gulf are clear and blue, characteristic of tropical waters the world over. Surface temperatures are high, the concentration of nutrients is low, and the salinity high throughout the year. The quantity of plankton in these waters (the standing crop) is low (Riley 1938), but the number of species is

probably relatively high. The temperature of this water drops markedly in the northern part of the Gulf for a few weeks during the winter, but as far as we know there is no seasonal change in the dinoflagellate fauna during this period.

The neritic waters may be considered to include the shallow periphery of the open Gulf in which the water is often of very high temperature, with variable salinity and nutrient content and in which wind mixing creates high turbidity, particularly in the winter when the density of the water is uniform from surface to bottom. The bays, bayous, and lagoons are also within this zone. These include mangrove swamps and other brackish water areas. Tidal effects are strong in the neritic zone, and the physical and chemical conditions of the water vary greatly throughout the year and, in some cases, within a daily tidal cycle. As a general rule, the species of dinoflagellates found in the neritic zone are distinct from those in open waters. However, the invasion of the coastal area with open Gulf water frequently obscures the zonation.

Sandy beaches in the intertidal zone constitute the third type of environment for the Gulf dinoflagellates. Certain specialized species belonging chiefly to the genus *Amphidinium* thrive in this situation in some parts of the world (Herdman 1924) causing discoloration of the sand and luminescence. When they are abundant, each kick of the heel at night on a wet, sandy beach will cause a flash of light. There are apparently no reports of such "dinoflagellate sand" for the Gulf coast, but a careful investigation of this zone might reveal a rich fauna.

Interest in the dinoflagellates of the Gulf, particularly along the west coast of Florida, was stimulated by the disastrous outbreaks of red tide which occurred in that area in 1946 and 1947 (Galtsoff, 1948; Gunter et al., 1948; Gunter, Smith, and Williams, 1947; Smith 1949). This red water was caused by a previously undescribed species, *Gymnodinium brevis* Davis (1948). The

study of the causes of these outbreaks was hampered by the lack of previous work in the area. As a consequence, the Marine Laboratory of the University of Miami and the Fish and Wildlife Service of the United States Department of the Interior initiated a study of the local plankton in order to gain some information regarding the causes of such plankton blooms. In the course of these studies some insight was gained of the normal dinoflagellate plankton along the west coast of Florida.

Davis (1950) reported upon a number of plankton samples collected there in 1947 and 1948. He listed 15 species of dinoflagellates.

He stated that the plankton of the west coast of Florida is markedly different from that of the east coast of Florida. Species found only on the west coast included the dinoflagellates, *G. brevis* and *Noctiluca scintillans* Macartney, which were found both inshore and offshore. In addition, a number of plankters were found only in the open waters of the Gulf. These included *Ceratocorys horrida* Stein.

Some species were found only in open waters but on both coasts. This group consisted of *Ceratium candelabrum* (Ehr.) Stein, *Pyrocystis fusiformis* W. Thomson, and *P. noctiluca* Murray. Occasionally, the open water species were found inshore. Davis interpreted this as indicating an admixture of open water with the inshore water. Davis and Williams (1950) listed seven species from brackish water in mangrove areas of southern Florida.

King (1950) listed 19 species of dinoflagellates from the west coast of Florida in a series of samples extending from inshore bays to a distance of 120 miles offshore and collected over a period of 10 months in 1949. About 10 of these species were not listed by Davis or Davis and Williams.

Additional species have been found by John Howell, biologist, Fish and Wildlife Service (unpublished data), along the west coast of Florida. *Ceratium pentagonum* Gourret occurred only at stations more than 30 miles offshore. A species of *Pyrocystis* (*Gymnodinium*) was present only offshore except in one sample. In a study of samples collected throughout the year Howell found the most commonly occurring species of dinoflagellates to be *Ceratium furca* (Ehr.) Dujardin and *C. tripos* (O. F. Muller) Nitzsch. Next in order of occurrence were *C. macroceros* (Ehr.)

Vanhoffen, *C. fusus* (Ehr.) Dujardin, *C. trichoceros* (Ehr.) Kofoid, *C. massilliense* (Gour.) Jörgensen *Peridinium depressum* Bailey, and *Dinophysis caudata* Saville-Kent. All of these appear to occur inshore as well as in the offshore waters of the Gulf. However, a more intensive study of the distribution of dinoflagellates along the coast may bring out more zonation than is at present apparent. The situation is complicated by the fact that typical open Gulf water with high salinity, low nutrient content, etc., sometimes extends up to the beach and, indeed, is carried into the bays by tidal action.

Howell found 11 species not reported by Davis or King. In addition to those listed above, there were 4 species of *Ceratium*: *C. carriense* Gourret, *C. horridum* Gran., *C. falcatum* (Kof.) Jörgensen, *C. praelongum* (Lem.) Kofoid. The last-named was found only once and is typical of a large number of very rare species which may be expected to be found occasionally in the open Gulf waters if any extensive investigation of these waters is made.

Other rare species found by Howell were *Pyrocystis hamulus* Cleve, *Pyrophacus horologicum* Stein, *Amphisolenia* sp., *Goniodoma* sp., and *Ornithocercus quadratus* Schütt. In a laboratory culture of Florida west coast water *Oxyrrhis marina* Dujardin flourished, and a large population developed.

Despite the richness of the dinoflagellate fauna in the Gulf, the actual concentration in terms of populations is normally very low. The concentration of dinoflagellates in numbers of cells per liter of sea water is usually less than 50 in the waters along the west coast of Florida. Yet, under unusual conditions which are still not clearly understood, a particular species may increase to enormous concentrations and cause serious disruption of the normal biological balance in the area involved.

Thus, in the Florida red tide of 1946 and 1947 the concentrations of *Gymnodinium brevis* Davis reached 60 million cells per liter (Davis 1948). These enormous concentrations cause the water to turn color, usually a brownish red, producing what is commonly called "red water" or "red tide."<sup>1</sup> Such concentrations of dinoflagellates are frequently accompanied by the death of fish

<sup>1</sup> Red tide in the Gulf of Mexico waters is discussed in an article by R. Lasker and F. G. Walton Smith pp. 173-176.

and other marine animals. There is every reason to believe that many species of dinoflagellates elaborate an extremely potent toxin either normally or under the conditions of population crowding. The two blooms cited above were associated with serious "fish kills" and death of much of the marine life in the area.

The presence of even normal numbers of dinoflagellates in the water may cause shellfish to become unfit for human consumption. Thus, regularly during the summer months the California sea mussel (*Mytilus californianus*) is likely to be lethal to humans when *Gonyaulax catenella* Whedon & Kofoid is abundant in the coastal water (Sommer et al., 1937), and the clams in certain areas of the Bay of Fundy are regularly toxic when *Gonyaulax tamarensis* Lebour occurs in the plankton (Medcof et al., 1947). Paralytic shellfish poisoning caused by eating such toxic shellfish has not been reported from the Gulf of Mexico. Connell and Cross (1950) found a dinoflagellate resembling *Gonyaulax catenella* associated with the death of fish in Offatts Bayou, an inlet of Galveston Bay, in 1949. Unfortunately, no specific identification of this organism was made. There is also strong evidence that the fish kills which regularly occur in Offatts Bayou are generally caused by the production of hydrogen sulfide or to suffocation due to stagnant conditions at the inner end of the inlet (Gunter 1942, 1951) rather than by a dinoflagellate bloom.

Toxic red water such as occurs regularly in the pearl oyster beds in Japan (Mitsukuri 1904) could be disastrous to the vast oyster industry in the Gulf, but apparently the Gulf oysters have been spared any such visitation so far.

Reports of red water on Campeche Banks, off Yucatán, are made occasionally by fishermen in that area, but to date it has not been possible to ascertain the causative agent. It is quite possible that a dinoflagellate is involved.

One of the great difficulties in dinoflagellate research is the fragility of the naked forms. Many of these are almost impossible to preserve but must be studied alive under the microscope. This feature might not be serious if the organisms were easily cultured, but they are notoriously difficult to grow in the laboratory. The classical monograph of the unarmored dinoflagellates by Kofoid and Swezy (1921) was based largely on examination of living specimens which regularly

dissolved before the eyes of the workers as they studied them. The Florida red tide was caused by such a naked form, *G. brevis*, which does not preserve in formalin. Special fixatives such as Bouin's solution and Schaudinn's solution do preserve some of these species but not without distortion.

However, a rich fauna of unarmored forms is not normally present inshore at Sarasota, Florida, where the workers of the Fish and Wildlife Service laboratory in their search for *G. brevis* have examined living material for 2 years and failed to reveal any *G. brevis*. They found only three other species of unarmored dinoflagellates. More work in other areas must be conducted before this problem can be solved.

The difficulty in making specific identification of dinoflagellates has led to a paucity of records of these interesting and important organisms. Painstaking microscopic work on the part of a specialist is necessary for the differentiation of many species, even of the thecate forms which preserve well.

In these species, an analysis of the plate pattern is necessary for identification. Few general planktologists have either the time or training to pursue this kind of work which involves difficult micro-orientation and dissection. Concentrated study by a number of specialists for a considerable period of time will be necessary before the dinoflagellate plankton of the Gulf will be adequately revealed to science.

Since most of the pelagic tropical species of dinoflagellates are worldwide in distribution, published works for other areas can be used for a study of the Gulf fauna. The most important of these are listed in the bibliography. Lebour's (1925) work is designed for northern seas but includes many tropical species. It is a very useful treatise, especially for a beginner who needs orientation. Kofoid and Swezy's (1921) monograph is a classic on the naked forms but must be augmented by later papers. Kofoid and Skogsborg's (1928) *Dinophysoidae* is another classic and covers that group in a comprehensive manner. The *Heterodiniidae* has been monographed by Kofoid and Adamson (1933). Most of the *Peridiniidae* are in need of monographic treatment. It is very difficult to identify the smaller species with present literature. For the *Ceratia* Jorgensen's (1911) monograph and Graham and

Bronikovsky's (1944) treatise on *Carnegie Ceratia* are quite useful. The most comprehensive systematic treatment of the dinoflagellates as a group is Schiller's *Dinoflagellata* in Rabenhorst's *Cryptogamen-Flora* (1931-37). The reports of the larger world expeditions complete the general literature on dinoflagellate taxonomy. Such references are included in the bibliography.

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